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# Gender bias in Nobel prizes

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**ABSTRACT** Strikingly few Nobel laureates within medicine, natural and social sciences are women. It is obvious that there are fewer women researchers within these fields, but does this still fully account for the low number of female Nobel laureates? We examine whether women are awarded the Nobel Prizes less often than the gender ratio suggests. Based on historical data across four scientific fields and a Bayesian hierarchical model, we quantify any possible bias. The model reveals, with exceedingly large confidence, that indeed women are strongly under-represented among Nobel laureates across all disciplines examined.

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## Introduction

In 2018, Professor D. Strickland received the Nobel Prize in Physics as the first woman in 55 years. From 1901 to 2018, the Nobel Prize in Physics has been awarded 112 times to 209 different candidates; among these are only two more women; namely M. Curie in 1903 and M. Goeppert Mayer in 1963. Women have historically occupied much fewer positions in academia than men have; hence, it is natural to expect more male Nobel laureates than female. However, the ratio of women in scientific professions has increased in all fields of science over the last decades (Shen, 2013). Despite this fundamental shift in the demography, the ratio of women Nobel laureates is still low and gives the impression of an increasing *gender gap* (Modgil et al., 2018). This gap is partially accounted for by the age discrimination of Nobel Prizes as laureates most often are well established senior researchers (Agarwal, 2018). In case seniority is the only important factor, we expect the Nobel awards to follow a binomial distribution with a probability given by the gender ratio among professors. For instance, if there is 10% women, we expect *ceteris paribus* a 10% chance that a woman is awarded the Nobel Prize. So does the gender ratio truly account for the few female Nobel laureates?

To investigate this, we compared the gender ratio of Nobel laureates in Physics; Chemistry, Economics, Physiology, and Medicine to the relevant gender ratios among scientists in the field. We use the gender distribution of senior faculty members in the US as proxy for a worldwide distribution and observe that women are awarded the Nobel Prize far less often than the faculty gender ratios suggest. More specifically, we find the probability that the distribution of Nobel Prizes is not favouring men, to be less than 4% for within all of the investigated fields.

## Methods

We used data of faculty members resolved on gender and fields from the National Science Foundation<sup>2</sup> as a proxy for a global distribution. This data only covers the period from 1973 to 2010; hence, we extrapolated the data with a logistic function to obtain the gender ratios,  $r$ , for different fields from 1901 to 2010. We note that the average age for Nobel laureates is 55 years and the findings, worthy of a Nobel Prize, are on average done 15 years earlier (Nobel, 2019). While we do not have access to the number of female and male faculty members, resolved by age, we define a lag time,  $\delta$ . With this, we presume that the relevant research originate from senior faculty members  $\delta$  years before.

We use a hierarchical Bayesian inference model and Hamiltonian Monte Carlo sampling (Carpenter et al., 2017). We model

the number of women laureates,  $f_{ij}$ , within the scientific field  $j$ , in year  $i$  as a stochastic binomial variable:

$$f_{ij} \sim B(N_{ij}, \theta_{ij}), \quad (1)$$

where  $B$  is the binomial distribution.  $N_{ij}$  and  $\theta_{ij}$  are the number of Nobel Prizes awarded and the corresponding success probability, i.e., the probability of a women being awarded, in year  $i$ , within the field  $j$ , respectively. In the case of no bias, we expect  $\theta_{ij}$  to be equal to the gender ratio,  $r_{i-\delta, j}$  some  $\delta$  years earlier. In order to quantify any bias we model the success probability,  $\theta_{ij}$  as

$$\theta_{ij} = \text{logit}^{-1}[\text{logit}(r_{ij}) + \log(\alpha_j)], \quad (2)$$

where  $\alpha_j$  is a positive, time independent, stochastic variable. We note that for  $r_{ij} \ll 1$  and  $\alpha_j r_{ij} \ll 1$  we can approximate Eq. (2) to the simple relation  $\theta_{ij} = \alpha_j r_{ij}$ . Here,  $\alpha_j$  is a bias parameter, such that when  $\alpha_j = 1$ , we have  $\theta_{ij} = r_{ij}$  i.e., women are awarded the Nobel Prize exactly as often as the gender ratio suggests. We use a hierarchical structure for the variable  $\alpha$ , assuming, for each scientific field,  $j$ , that the mean and standard deviation of  $\log(\alpha_j)$  is drawn from stochastic (hyper) variables  $\mu$  and  $\sigma$ . Hence, we assume some similarity between the four different  $\alpha_j$ 's. We use

$$\log(\alpha_j) \sim N(\mu, \sigma) \quad (3)$$

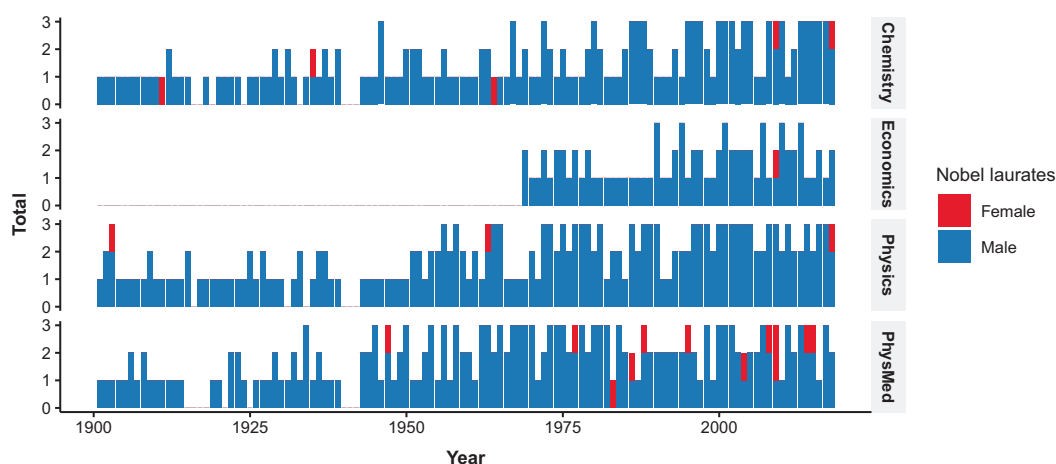
$$\mu \sim N(0, 1) \quad (4)$$

$$\sigma \sim N(1, 0.5), \quad (5)$$

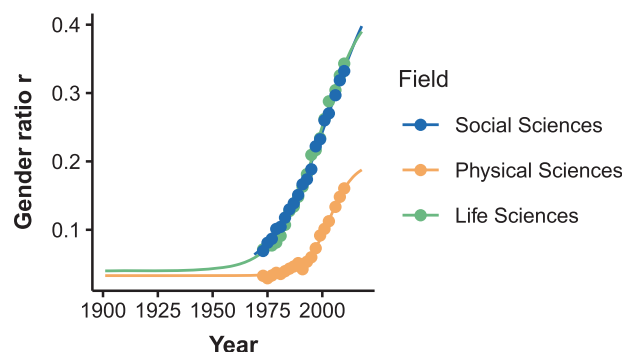
where  $N$  is the normal distribution. We notice that for  $\mu = 0$  we have that  $\text{Median}(\alpha_j) = 1$  corresponding to no gender bias. Hence, we choose a weakly informative prior distribution for  $\alpha_j$  with a median of 1, see Fig. 3. We further note that the results were found significantly robust on the choice of the hyper parameter  $\mu$  (Eq. (4)) and on the standard deviation of the normal distribution, Eq. (5).

## Results

Since the first Nobel Prizes were awarded in 1901 there has been 688 Nobel laureates within the fields of Chemistry, Economics, Physics, and Medicine; among these are only 20 women (21 prizes as M. Curie received the prize twice), see Fig. 1. Among the Nobel laureates of economics there is one woman; namely Professor E. Ostrom (2009) which corresponds to 2%. In Medicine, 12 women have been awarded over the years which 6% of the laureates. It is obvious that these differences reflect, to some extent, the gender ratios within the field. However, the gender



**Fig. 1** Gender distribution of Nobel Prizes. Bar plot of the scientific Nobel Prizes from 1901 to 2018 resolved by field and gender. (Nobel, 2019)

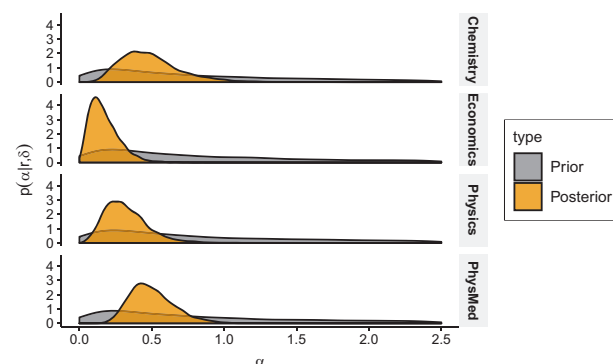


**Fig. 2** Gender ratio,  $r$ , defined as the number of women relative to all faculty members, versus years: data (points) from the National Science Foundation (NSF, 2018) and fit of a logistic function (line)

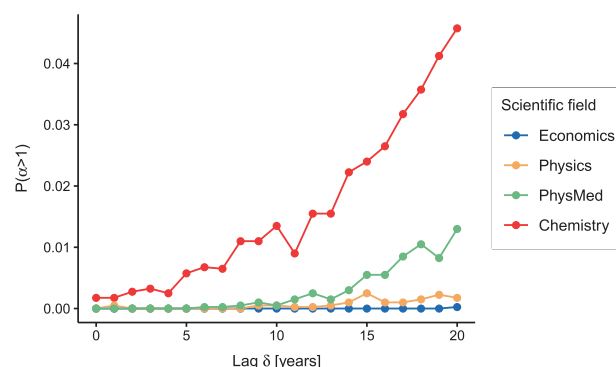
distribution of faculty members evolves and for every instance in time, the gender distribution among senior faculty members is different from junior faculty members. As the average age of Nobel laureates is 55 years (Nobel, 2019), we assume that the Nobel laureates are sampled from a gender distribution of senior faculty members. Moreover, Nobel laureates did their ground breaking findings a few decades prior to the award (the average is 15 years (Nobel, 2019)). To account for this, we assume that today's Nobel laureates are sampled from senior faculty members  $\delta$  years ago.

We examined the fraction of female faculty members relative to all faculty members which we denoted gender ratio,  $r$ . We used the gender ratios of senior faculty members at US university departments as a proxy for a global distribution. The data were retrieved from the National Science Foundation (NSF, 2018) and covers the period from 1973 to 2010. For completeness, we fitted with a logistic function and extrapolated the data back in time to cover the entire period of Nobel awards from 1901 to 2010, see Fig. 2. In the data, both Chemistry and Physics are gathered under Physical sciences. Hence, we used this gender ratio for both the Physics and Chemistry Nobel Prizes. Furthermore, for the Nobel Prize in Economics we used the gender ratio of senior faculty members from Social sciences. Most probably, this leads to a slight overestimation of the bias within economics, since economics may have a smaller gender ratio than the overall ratio within Social sciences. We use a hierarchical model to quantify possible gender bias in the awarding of Nobel Prizes using Bayesian inference through Hamiltonian Monte Carlo sampling, see Methods section. The gender bias is described by the parameter  $\alpha$  and when  $\alpha < 1$  ( $\alpha > 1$ ) women are awarded the Nobel Prize less (more) often than the gender ratio suggests. The sampled prior and posterior probability density distributions,  $p(\alpha | r, \delta)$ , is illustrated in Fig. 3, for a lag of  $\delta = 10$  and ratios  $r$ . From the prior distribution (grey), we confirm that we chose a weakly informative prior, allowing value of  $\alpha$  both well below and above 1. For all four Nobel Prizes, the posterior distributions shows a significant bias against women with mean values of the posterior probability density  $\langle \alpha \rangle < 1$  and a total probability of being larger than unity,  $P(\alpha \geq 1) = 1 - \int_0^1 p(\alpha | r, \delta) d\alpha$ , found to be less than a few percent. To investigate how sensitive the measured bias is to the choice of  $\delta$  we repeated the analysis in the range from  $0 \leq \delta \leq 20$ . For all values of  $\delta$ , sample values of  $\alpha$  were predominantly smaller than unity. This is summarized in Fig. 4, which shows the probability of  $\alpha$  being larger than 1,  $P(\alpha \geq 1)$  versus delay,  $\delta$ .

We anticipate that the variations within the different fields, to some extent, reflect the granularity of categories in the historical gender ratios. For instance, for Economics (blue curve) we probably overestimated the bias by comparing with the gender



**Fig. 3** Prior (grey) and posterior (orange) probability density of  $\alpha$ , for  $\delta = 10$ . The prior distribution was set giving a median of 1, see Eq. (3) and Eq. (4). Values of  $\alpha$  less (more) than unity signify fewer (more) Nobel Prizes awarded women than the gender ratio suggests



**Fig. 4** Estimated probability of  $\alpha$  being more than one,  $P(\alpha \geq 1) = 1 - \int_0^1 p(\alpha | r, \delta) d\alpha$ , i.e., the probability that women are favoured versus delay parameter,  $\delta$

ratio within Social Sciences (where we believe the ratio is larger). In contrast, for Chemistry (red curve) we were likely to underestimate the bias as we collated the prizes with the ratio of Physical Sciences, which includes both Physics and Chemistry. Therefore, we do not conclude that Nobel Prizes for some scientific field have a larger bias, than for others. Regardless of this, we find that the possibility that Nobel laureates are awarded without disfavoured women is less than 4% for lag times less than 20 years. This firm evidence shows that women are disfavoured, i.e., female senior scientists are less likely to be awarded a Nobel Prize than their gender ratio suggests. Furthermore, one could argue that the findings are often done early in the career, i.e., before tenure, where gender ratios are more balanced. If this is true, our model underestimates the bias against women.

## Discussion

The last 15 years 10 women were honoured with the Nobel Prize within Physics, Chemistry, Economics, and Medicine and Physiology this is exactly the same as the first 100 years of the Nobel Prize's history (11 prizes as M. Curie received it twice). Despite this fact, using a hierarchical Bayesian interference model, we found that the gender distribution in Nobel Prizes includes a bias against women with more than ~96% probability. Hence, even women that resist the *leaky pipeline* (Pell, 1996; Goulden et al., 2009) and become permanent staff members do not have equal chances to be awarded the Nobel Prize.

However, our models do not propose that this bias arises from an unfair evaluation of nominees by the Nobel committees.

Unfortunately, we do not have the possibility to test this hypothesis as nominators (and nominees) are guaranteed full anonymity for 50 years (Nobel, 2019). Nevertheless, we believe that this divergence occurs at multiple earlier steps in the careers of potential Nobel laureates. This means that there is not an equal possibility for both genders to be nominated for a Nobel Prize. We speculate that there are limitations for women to enter the pool of very well esteemed scientists worthy of a nomination. This hindrance could be related to family life; as female laureates are significantly less likely to be married (63 versus 97%) and/or have children (55 versus 86%) than their male counterparts (Charyton et al., 2011). This is in accordance with the general assumption that carrying obligations is one of the main causes of pipeline leaks (Fig. 1 in Ref. (Goulden et al., 2009)). Combined with a lack of role models (Robinson, 2011) an academic career is less attractive for the junior faculties' women (Fig. 8 in Ref. (Goulden et al., 2009)). Furthermore, there are indications that men in academia are more likely to be provided the resources and support needed for an excellent scientific production (Xie and Shauman, 2003). In contrast, due to fewer resources, women's publication index remains low and consequently they are less likely to be nominated to the prestigious award. This is reflected by the fact that female laureates have a significantly lower publication index than their male counterpart (on average 219 versus 358) (Charyton et al., 2011). These differences in family obligations and resources suggests that men are more prone to end up in the pool of possible Nobel nominees.

We are aware that the gender bias is likely to be one bias among many, e.g., affiliation, sexuality, and nationality, retractable from the set of Nobel laureates in Science. Nevertheless, we find the gender ratio is symptomatic in the sense, that women should have nothing else against them to be awarded the Nobel Prize (Abir-Am, 2010). Therefore, these results are not only of relevance for future Nobel laureates, but for all future faculty members.

### Data availability

The datasets analysed during the current study are available in the Dataverse repository: <https://doi.org/10.7910/DVN/MRLDMQ>. These datasets were derived from the following public domain resources: <https://www.nsf.gov/statistics/seind14/content/chapter-5/at05-15.pdf>, <https://www.nobelprize.org>

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### Additional information

**Competing interests:** The authors declare no competing interests.

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